FURNACE ASSEMBLY FOR HEATING AN OPTICAL WAVEGUIDE PREFORM

Field of the Invention

The present invention relates to furnaces for heating an optical waveguide preform, and, more particularly, to such a furnace which uses a flow of processing gas.

Background of the Invention

Inert gases such as helium (He) are used in large volumes in the manufacture of optical fiber or waveguides. For example, a soot or glass preform may be placed in a consolidation furnace having a muffle and a plate covering an end of the muffle, the plate having a hole or other leak paths through which ambient air may enter the muffle. A flow of He may be passed through the furnace and about the preform to eliminate or reduce the entry of air into the furnace where it may otherwise cause defects in the preform or damage the furnace. High flow rates of He may be required to adequately seal the furnace from air. Similarly, during preform drying operations, a relatively high rate of flow of chlorine gas (Cl_2) may be used to prevent or reduce the introduction of air into the drying furnace. He and Cl_2 may be costly. Moreover, the He or Cl_2 exiting the furnace typically must be treated for pollution abatement, which may substantially increase the costs of manufacturing fiber.

Summary of the Invention

According to embodiments of the present invention, a furnace assembly for heating an optical waveguide preform includes a furnace. The furnace includes a muffle and a heating device. The muffle defines a furnace passage, the passage having a length extending from a first end to a second end. The heating device is operative to heat the furnace passage. A process gas supply provides a process gas to the furnace passage. A handle is disposed in the furnace passage and is adapted to hold the waveguide preform. A flow shield is positioned between the first and second ends and extends across the furnace passage between the handle and the muffle. The flow shield is arranged and configured to restrict flow of the process gas from the first end to the second end of the furnace passage.

The flow shield may serve to reduce or minimize the amount of process gases needed. Further, the flow shield may reduce or minimize the detrimental effects that O_2, H_2, H_2O, N_2, CO_2 and other gases may have on the preform and resultant fibers drawn therefrom.

According to further embodiments of the present invention, a furnace assembly adapted to heat an optical fiber preform includes a muffle tube defining a furnace passage. The passage includes a length extending from a first end to a second end. A process gas supply is adapted to supply a process gas in the passage directed from the first end to the second end. A handle is adapted to suspend the preform within the passage. A flow shield is positioned in the passage between the preform and the second end and extends between the handle and the muffle tube. The flow shield is configured to enable restriction of flow of the process gas.

According to further embodiments of the present invention, a furnace assembly adapted to heat an optical fiber preform includes a muffle tube including a passage. A top plate is mounted on an end of the tube. A gas supply is provided for supplying process gas to the passage. A handle traverses the top plate and is adapted to suspend the preform in the passage. A flow shield is positioned in the passage between the preform and the top plate. The flow shield is configured to enable restriction of the gas.

According to further embodiments of the present invention, a flow restrictor assembly for an optical fiber furnace adapted to heat an optical fiber preform includes a top plate having a passage of a first dimension formed therethrough. At least one solid flow restrictor having a hole of a second

dimension formed therethrough is provided. A handle is inserted through the passage and the hole. The handle is adapted to suspend the preform. The first dimension is larger than the second dimension.

According to method embodiments of the present invention, a method of manufacturing an optical fiber preform includes flowing a process gas in a furnace passage of a muffle tube from a first end to a second end. The furnace passage has the optical fiber preform mounted therein. Flow of the process gas is restricted using a flow shield positioned in the passage between the preform and the second end and extending between a handle and the muffle tube.

Objects of the present invention will be appreciated by those of ordinary skill in the art from a reading of the figures and the detailed description of the preferred embodiments which follow, such description being merely illustrative of the present invention.

Brief Description of the Drawings

Figure 1 is a schematic, fragmentary view of a furnace assembly according to embodiments of the present invention;

Figure 2 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention;

Figure 3 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention;

Figure 4 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention;

Figure 5 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention;

Figure 6 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention;

Figure 7 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention;

Figure 8 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention; and

Figure 9 is a schematic, fragmentary view of a furnace assembly according to further embodiments of the present invention.

Detailed Description of the Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

With reference to **Figure 1**, a furnace assembly **100** according to embodiments of the present invention is shown therein. The furnace assembly **100** is adapted to heat an optical waveguide preform **5** such as the soot preform shown. The furnace assembly **100** is adapted to prevent or reduce exposure of the preform **5** to ambient air while allowing the use of a reduced flow rate of process gas.

The preform **5** may be a soot preform (as illustrated) or a glass preform which may be formed from a soot preform. The soot preform may be formed using any suitable method, such as chemical vapor deposition (CVD). Suitable methods for forming soot preforms are known to those of skill in the art and include outside vapor deposition (OVD). For example, U.S. Patent No. 4,629,485, the disclosure of which is hereby incorporated herein by reference, discloses suitable methods and apparatus for forming a soot preform. The soot preform **5** may be formed of pure silica or may be formed of doped silica (for example, silica doped with germania, fluorine, chlorine and/or phosphorus). The preform **5** may include a passage extending the full length thereof from which a mandrel of the chemical vapor deposition apparatus has been removed.

The furnace assembly **100** includes a furnace **101**, a process gas supply system **150** and a preform positioning and rotating system **140**. The furnace **101** includes a tubular muffle **110** having an inlet opening **112**, an outlet opening **114** and an annular flange **116**. The muffle **110** defines a furnace passage **111** having a lower end **110A** and an upper end **110B**. A top plate **120** covers the outlet opening **114** and interfaces with the flange **116**. The top plate **120** has a central opening **122**. The muffle **110** and top plate **120** are preferably formed of fused silica, fused quartz, ceramic, ceramic coated fused silica, or ceramic coated fused quartz.

A heating device **118** is positioned about the muffle **110**. The heating device **118** may be, for example, a resistance coil or element operable to heat the

muffle **110**. Optionally, the heating device **118** may be an induction coil and an element including a susceptor surrounding the muffle **110**.

The positioning and rotating system **140** includes a handle **130**. The handle shaft or body **130** includes a handle body **132** extending through the opening **122** and into the passage **111** through the opening **114**. A coupling portion **134** is formed on the lower end of the handle body **132** and is arranged and configured to hold and suspend the preform **5**. The handle body **132** and the coupling portion **134** are preferably formed of fused silica, fused quartz, ceramic, ceramic coated fused silica, or ceramic coated fused quartz.

The handle **130** is connected to a shuttle **142** on a rail **146** which is in turn mounted on a stationary support **149**. A motor **148** is operable to move the shuttle **142** up and down along the rail **146** and to thereby raise and lower the handle **130** and the preform **5** with respect to the muffle **110** and the top plate **120**. A motor **144** is operable to rotate the handle **130** and to thereby rotate the preform **5** with respect to the muffle **110** and the top plate **120**.

The process gas supply system **150** includes a dopant gas supply **152**, a drying gas supply **154** and an inert gas supply **156**. Valves **152A**, **154A** and **156A** are provided to control flow of the gases from the supplies **152**, **154** and **156**, respectively, into a feed line **157**. The process gas **G** from the feed line **157** enters the passage **111** through the inlet opening **112** and flows upwardly in the direction **D** from the end **110A** to the end **110B** about the preform **5**. As discussed in more detail below, the process gas **G** ultimately exits the furnace passage **111** through the opening **122** and/or gaps between the top plate **120** and the flange **116**. Depending on the selected gas and other process parameters, the process gas that exits the passage **111** may be modified. For example, if a dopant gas is used, portions of the dopant may be retained in the preform **5**. Similarly, if a drying gas is used, hydroxyl ions and other constituents may be exhausted with the process gas **G**.

In a first embodiment, a flow shield **160** is mounted on the handle body **132** in the passage **111** between the preform **5** and the upper end opening **114**. The periphery defined by the outer peripheral wall **160A** of the flow shield **160** preferably has a shape that is complimentary to the shape of the passage **111**. More preferably, the flow shield **160** is a circular disc and the passage **111** and the peripheral wall **160A** are each cylindrical.

The handle body **132** extends through a central hole **160B** in the flow shield **160**. A cylindrical spacer **162** spaces the flow shield **160** from the coupling portion **134**. Optionally, the flow shield **160** may be secured to the handle body **132** (*e.g.*, by frictional fit or fusing).

The peripheral wall **160A** and the adjacent portion of the inner surface **115** of the muffle **110** define an annular restrictive flow passage **161** therebetween and surrounding the flow shield **160**. The flow shield **160** effectively divides the passage **111** into an upper isolation chamber **102** above the flow shield **160** and a lower process chamber **104** below the flow shield **160**. The chambers **102** and **104** are fluidly connected by the restrictive flow passage **161**.

Preferably, the flow shield **160** and the spacer **162** are formed of fused quartz, fused silicon, ceramic or silicon carbide. Preferably, the thickness **T** of the flow shield **160** is greater than about 6 mm and, more preferably, greater than about 38 mm. The height **S1** of the spacer **162** is preferably between about 50 mm and 0.75 meter. Preferably, the peripheral wall **160A** is substantially fully vertically oriented. Preferably, the gap width **W1** of the restrictive flow passage **161** is no more than about 25 mm. More preferably, the gap with **W1** is between about 2.5 mm and 12.5 mm. The height **S2** of the upper chamber **102** is preferably between about 25 mm and 1 meter when the preform **5** is in the desired position in the furnace **101**.

A plurality of washers **172, 174** are positioned over the opening **122** with the handle body **132** extending through central openings **172A, 174A** formed therein. Preferably, the openings **172A, 174A** are sized to fit loosely (slip fit) against the handle body **132**. The washers **172, 174** are preferably formed of solid fused silica, fused quartz, ceramic, or silicon carbide.

The furnace assembly **100** may be used in the following manner. The preform **5** is suspended from the coupling portion **134**. The preform **5**, the handle **130**, the flow shield **160** and the spacer **162** are lowered into the passage **111** using the motor **148**. The preform **5** is lowered until the top plate **120** comes to rest on the flange **116** as shown in **Figure 1**.

The selected process gas **G** is introduced from the appropriate supply or supplies **152, 154, 156** by opening the associated valve or valves **152A, 154A, 156A**. For example, if the intended process is a doping process, the dopant supply valve **152A** is opened. Suitable dopant gases include Cl_2, SiF_4, CF_4, SF_6, NF_3,

$GeCl_4$, $SiCl_4$, $POCl_3$, BCl_3, BF_3, PCl_3, C_2F_6, and CO, as well as mixtures thereof. Alternatively, if a drying process is desired, the valve **154A** is opened. Suitable drying gases include Cl_2, SiF_4, CF_4, C_2F_6, SF_6, NF_3, $SiCl_4$, $GeCl_4$, $POCl_3$, BCl_3 and BF_3. Where an inert gas is desired (for example, during a sintering process), the valve **156A** is opened. Suitable inert gases include He, Ar, N_2 and Ne.

Additionally, the heating device **118** is operated to heat the muffle **110** to the desired temperature. The handle **130** may be rotated by the motor **144**. The preform **5**, the flow shield **150**, the spacer **162**, and the washers **172, 174** will rotate with the handle **130**.

The process gas **G** enters the muffle **110** through the inlet opening **112** and passes in the direction **D** around the preform **5** up to the flow shield **160**. The process gas **5** then flows through the restrictive flow passage **161** and into the upper chamber **102**. Finally the process gas **G** exits the furnace passage **111** through the opening **122** and/or the interface between the flange **116** and the top plate **120**. Notably, the washers **172, 174** and the mating surfaces of the top plate **120** and the flange **116** further restrict flow of the process gas **G** out of the furnace passage **111**. The washers **172, 174** allow suitable clearance between the top plate **120** and the handle **132**.

The flow of the process gas **G** out of the furnace passage **111** as described above serves to prevent or inhibit entry of air through the interface between the top plate **120** and the flange **116** and through the opening **122**. Moreover, the restrictive flow passage **161** and the process gas **G** flowing upwardly through the restrictive flow passage **161** prevent or inhibit any air which does enter the upper, isolation chamber **102** from entering the lower chamber **104** where it might otherwise contaminate the preform **5** or the lower portion of the muffle **110**.

Preferably, the flow rate of the process gas **G** through the furnace passage **111** is less than 30 slpm (standard liters per minute). More preferably, the flow rate of the process gas **G** through the passage **111** is less than 20 slpm. Most preferably, the flow rate of the process gas **G** through the furnace passage **111** is less than 10 slpm.

As noted above, the flow shield **160** and the spacer **162** are preferably formed of fused silica, fused quartz, ceramic, ceramic coated fused silica, or ceramic coated fused quartz. As such, they do not contribute to contamination of the preform **5** when heated to operating temperatures in the range of about 650 to

2100 °C and, more particularly, in the range of 900 to 1600 °C. The spacer **162** spaces the flow shield **160** from the preform **5** so that heat reflected downwardly from the flow shield **160** does not cause nonuniform heating of the upper portion of the preform **5**.

With reference to **Figure 2**, a furnace assembly **200** according to further embodiments of the present invention is shown therein. The furnace assembly **200** corresponds to the furnace assembly **100** except as follows. A flow shield **260** and a spacer **262** corresponding to the flow shield **160** and the spacer **162** are provided, the flow shield **260** forming a restrictive flow passage **261** with the muffle **210**. Additionally, a second cylindrical spacer **266** extends upwardly up from the flow shield **260** and about the handle body **232**. A second flow shield **268** is mounted on the spacer **266**. The outer peripheral wall of the second flow shield **268** defines a second restrictive flow passage **267** with the adjacent portion of the inner surface of the muffle **210**. In use, the process gas **G** flows up the passage **211** in the direction **D**, through the restrictive flow passage **261**, into the chamber **202** between the flow shields **260** and **268**, through the restrictive flow passage **267**, into the chamber **206** between the flow shield **268** and the top plate **220**, and finally out of the passage **211** in the manner described above. Accordingly, the face shield **268** and the upper chamber **206** provide further barriers to entry of air into the lower chamber **204**.

Preferably, the gap width of the restrictive flow passage **267** is the same as described above with regard to the restrictive flow passage **261**. The flow shield **268** may be formed in the same manner as described above with regard to the flow shield **160**. The spacer **266** is preferably formed of fused silica, fused quartz, ceramic, ceramic coated fused silica, or ceramic coated fused quartz, as well as combinations thereof. Preferably, the spacing **S3** between the flow shields **260, 268** is between about 25 mm and 0.5 meter.

With reference to **Figure 3**, a furnace assembly **300** according to further embodiments of the present invention as shown therein. The furnace assembly **300** corresponds to the furnace assembly **100** except as follows. A flow shield **360** and a spacer **362** corresponding to the flow shield **160** and the spacer **162** are provided. A cylindrical shield collar **370** is secured to and extends upwardly from the flow shield **360**. The outer peripheral wall of the flow shield **360** and the outer surface of the collar **370** define a lengthwise restrictive flow passage **371** with the adjacent

portion of the inner surface of the muffle **310**. Additionally, a second cylindrical shield collar **374** is secured to and extends downwardly from the lower surface of the top plate **320** and into the collar **370**. The inner surface of the collar **374** defines a second lengthwise restrictive flow passage **377** with the adjacent portion of the outer surface of the handle body **332**. The flow shield **360**, the collar **370** and the collar **374** define a connecting passage **375** therebetween.

In use, the process gas **G** flows up the passage **311** in the direction **D** and through the restrictive flow passage **371**. While a portion of the process gas **G** may exit the muffle **310** through the interface between the top plate **320** and the muffle **310**, a remaining portion of the process gas **G** will pass through the connecting passage **375** and the restrictive flow passage **377**.

The collars **370** and **374** are preferably formed of fused silica, fused quartz, ceramic, ceramic coated fused silica, or ceramic coated fused quartz, or combinations thereof. The gap width **W3** of the restrictive flow passage **371** is preferably between about 2.5 mm and 12.5 and, more preferably, no greater than 25 mm. The length **R1** of the restrictive flow passage **371** is preferably between 25 mm and 0.5 meter. The spacing **W4** between the washers **372**, **374**, and the handle **332** is preferably between about 0.25 mm and 2 mm. The length of the restrictive flow passage defined between the washers **372**, **374**, and the handle **332** is preferably between about 0.25 mm and 5.0 mm. The gap width **W5** of the restrictive flow passage **377** is preferably between 1 mm and 20 mm. The length **R2** of the restrictive flow passage **377** is preferably between 25 mm and 0.25 meter.

With reference to **Figure 4**, a furnace assembly **400** according to further embodiments of the present invention is shown therein. The furnace assembly **400** corresponds to the furnace assembly **100** except as follows. The furnace assembly **400** includes three flow shields **460**, each corresponding to the flow shield **160**, in a stacked arrangement. The flow shields **460** may be fused or otherwise affixed to one another. The outer peripheral walls of the flow shields **160** in combination form a lengthwise extending restrictive flow passage **461**. The gap width **W6** of the restrictive flow passage **461** is preferably between about 2.5 mm and 12.5 mm and no greater than 25 mm. The length **R3** of the restrictive flow passage **461** is preferably between about 18 mm and 125 mm.

With reference to **Figure 5**, a furnace assembly **500** according to further embodiments of the present invention is shown therein. The furnace assembly **500** corresponds to the furnace assembly **100** except as follows. The furnace assembly **500** includes a flow shield **560** corresponding to the flow shield **160** except that the central opening **560A** of the flow shield **560** is enlarged to provide clearance for the handle body **532** and to define a restrictive flow passage **563**. Preferably, the gap width **W7** of the restrictive flow passage **563** is between about 1 mm and 20 mm.

The flow shield **560** is suspended from the top plate **520** by connecting members **568** which are secured to each of the flow shield **560** and the top plate **520**, for example by fusing. Preferably, the connecting members **568** are rod shaped. Alternatively, the connecting member may be a tube with holes formed therein. The connecting members **568** are preferably formed of fused silica, fused quartz, ceramic, ceramic coated fused silica, or ceramic coated fused quartz. The spacing **S4** between the flow shield **560** and the top plate **520** is preferably between about 125 mm and 0.6 meter.

The outer peripheral wall of the flow shield **560** defines a restrictive flow passage **561** with the inner surface of the muffle **510**. Preferably, the restrictive flow passage **561** has a gap width the same as described above with regard to the restrictive flow passage **161**.

The furnace assembly **500** may be operated in the same manner as described above with regard to the furnace assembly **100**, except that the flow shield **560** is not raised and lowered with the preform **5**. Additionally, the process gas **G** may flow through the restrictive flow passage **563**. The furnace assembly **500** may be preferred where it is desired to reduce the risk of impact between the flow shield **560** and the muffle **510**.

With reference to **Figure 6**, a furnace assembly **600** according to further embodiments of the present invention is shown therein. The furnace assembly **600** corresponds to the furnace assembly **100** except as follows. Three flow shields **660, 667, 669** corresponding to the flow shield **160** are stacked with spacers **666** and **668** interposed therebetween. The flow shields **660, 667** and **669** define a lower chamber **604** and upper chambers **602A, 602B** and **602C**. The flow shields **660, 667, 669** define restrictive flow passages with the muffle **610** in the same manner as described above with regard to the flow shield **160**.

The handle body **632** includes a handle passage **636** formed therein and fluidly communicating with radially extending gas openings **638**. The gas openings **638** are positioned between the flow shields **667** and **669**. A supply of inert gas **656** is fluidly connected to the handle passage **636** by a line **658**. By operation of the valve **656A**, inert gas **F** may be introduced into the handle passage **636** such that the inert gas exits through the gas openings **638** and into the chamber **602B**. The inert gas **F** thereafter flows up into the chamber **602C** and out of the muffle **610** with the process gas **G**. In this manner, the inert gas serves as a purge gas to provide an additional barrier to entry of air.

Preferably, the inert gas **F** is Ar, He, or N_2. Alternatively, the same gas (and gas supply) as used for the process gas **G** may be used for the gas **F** supplied through the handle passage **636**. Alternatively, the inert gas may be supplied into the chamber **602C** through a hole in the top plate or a similar passage.

With reference to **Figure 7**, a furnace assembly **700** according to further embodiments of the present invention is shown therein. The furnace assembly **700** corresponds to the furnace assembly **100** except as follows. In the furnace assembly **700**, the flow shield **160** and the spacer **162** are omitted. A toroidal flow shield collar **780** is secured to and depends from the top plate **720** and surrounds the handle body **732**. An inner surface **780A** of the flow shield collar **780** defines a first restrictive flow passage **782** with the handle body **732**. An outer surface **780B** of the collar **780** defines a second restrictive flow passage **783** with the inner surface of the muffle **710**. In use, the flow of the process gas **G** out of the muffle **710** is restricted by the restrictive flow passages **782** and **783**, and, likewise, entry of air into the lower chamber **704** is restricted.

The gap width **W8** of the restrictive flow passage **782** is preferably between about 1 mm and 20 mm. The length **R4** of the restrictive flow passage **782** is preferably between about 25 mm and 0.3 meter. The gap width **W9** of the restrictive flow passage **783** is preferably between about 2.5 mm and 12.5 mm and no greater than 25 mm. The length **R5** of the restrictive flow passage **783** is preferably between about 75 mm and 0.25 meter.

With reference to **Figure 8**, a furnace assembly **800** according to further embodiments of the present invention is shown therein. The furnace assembly **800** corresponds to the furnace assembly **300** except as follows. The flow shield collar **370** is omitted. A handle passage **836** extends through the handle body **832** and

the coupling portion **834**. The gas supplies **852, 854, 856** are each fluidly connected to the handle passage **836** by a line **858**. By opening the valve **858A**, the process gas **G** supplied through the inlet opening **812** may also be supplied through the handle passage **836**. This portion of the process gas **G** flows down through the handle passage **836** and through a passage **5A** in preform **5**. The process gas **G** exits the passage **5A** at the lower end of the preform **5** and, along with the portion of the process gas introduced through the inlet opening **812**, flows up the passage **811** and out of the muffle **810**. This apparatus and process may be particularly advantageous for drying (*e.g.*, with chlorine).

With reference to **Figure 9**, a furnace assembly **900** according to further embodiments of the present invention is shown therein. The furnace assembly **900** corresponds to the furnace assembly **100** except as follows. The inner surface **915** of the muffle **910** includes a recessed upper portion **915A** which forms an annular ledge **915B**. The flow shield **960** has a central opening **960B** that is sized and shaped to define an annular restrictive flow passage **963** between the flow shield **960** and the handle body **932**.

In use, the handle **930** is lowered until the flow shield **960** rests on the ledge **915B**. The handle **930** may be rotated to rotate the preform **5**. The restrictive flow passage **963** allows the handle **930** to be rotated without rotating the flow shield **960**. The process gas **G** may flow upwardly between the flow shield **960** and the ledge **915B** and/or through the restrictive flow passage **963**.

As discussed above, the furnace assemblies **100-900** according to embodiments of the present invention shield the preform **5** from ambient air while requiring a reduced flow of process gas (*e.g.*, dopant gas, drying gas or inert or other purging gases). The reduced flow rate reduces the amount of gas required for the process as well as the amount of exhaust gas which must be scrubbed, recycled or otherwise handled. The reduced flow rate may allow increased reacting time and thereby improved doping and/or cleaning. For example, a process gas including chlorine may be used while drying, cleaning, doping, and/or sintering. A reduced flow rate of the chlorine-containing process gas may be used during the sintering step to allow improved doping and/or cleaning. Preferably the flow rate of the chlorine-containing process gas while sintering is less than 30 slpm, more preferably less than 20 slpm, and most preferably less than 10 slpm.

Various aspects and features of the furnace assemblies **100-900** may be combined. For example, the furnace assembly **200** may be provided with a handle passage, gas openings and supply lines corresponding to the passage **636**, the gas openings **638** and the line **658**. The flow shield collar **780** may be used in combination with a flow shield attached to the handle (*e.g.*, corresponding to the flow shield **160**) or a flow shield attached to the top plate **720** (*e.g.*, corresponding to the flow shield **500**). Moreover, while reference is made herein to a "top" plate, upper and lower ends and chambers, upward and downward directions and flows, and the like, the furnace assemblies **100-900** may be reoriented.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the invention.